L-03

Influence of deformation distribution in console-probe-sample system on AFM measurements

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In [1, 2] some drawbacks of an optical lever method to detect the cantilever deflections in the atomic force microscope (AFM) were analyzed. In this method, only two angles, bending and torsion of the cantilever are measured, while the displacement vector or the interaction force may have three spatial components. The state with the probe clamped at the sample surface moving upward leads to the anomalous buckling of the cantilever console (the deviation angle profile along the console has an extreme), in contrast to the bending (the profile is monotonous) for the state when the probe is sliding. Since the deviation angle is detected only at one point of the console, anomalous buckling may lead to ambiguous, erroneous measurements not only of the amplitude but also of the interaction force sign. This ambiguity was recently partly overcome, after an appearance of the AFM device having both optical lever and interferometric sensor [3].

The lecture discusses calculations of deformations in the console-probe-sample system, that permit to reveal clamped or slipping states in the probe-sample contact. The calculations were performed taking into account the stiffness tensors to describe: console; probe, attached to the console edge; and sample. A general solution is presented for three types of holonomic constraints: clamped contact; probe slides in the selected direction; probe slides in the selected plane. Also, two closely related particular solutions are investigated: 1) rectangular console; probe approximated by a truncated cone with an axis not coinciding with Z direction, "infinitely rigid" sample; 2) rectangular console; "infinitely rigid" probe, mechanically anisotropic sample with finite rigidity.

The calculations are checked in AFM experiments on various test samples: cleaved GaAs (110). TGG1 sample, microdrops of Ga, Hg, polymer glue UV50, polydimethylsiloxane, glycerol. Also, we used the data of AFM studies of native, living cells (PeakForce QNM mode, under conditions as close to physiological as possible): sensory neurons and fibroblasts of chick embryos, rat erythrocytes [4].

The lecture materials may be useful for: intellectual "upgrade" of the optical lever method; developing accurate nanomechanical measurements of solid state objects, polymers, living cells; optimizing cantilever parameters for quantitative piezoresponse force microscopy; creating effective algorithms for nanoparticle manipulation.

1. S. Fujisawa et al., *Rev. Sci. Instr*. **65**, 3, 644 (1994).
2. H. Kawakatsu et al., *Jpn. J. Appl. Phys*. **34**, 3400 (1995).
3. https://www.oxford-instruments.com
4. M.M. Khalisov et al., *IOP Conf. Series: Materials Science and Engineering* **256**, 1, 012010 (2017).